# "Simulation of Extreme Arctic Cyclones in IPCC AR5 Experiments"

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Award Number: N000141110611

## LONG-TERM GOALS

The primary goals of this project are to assess the ability of the current generation of global climate models (GCMs) to simulate extreme Arctic cyclones and identify changes in the characteristics of these storms caused by greenhouse-forced climate change to present.

## OBJECTIVES

These goals are being addressed through the following questions. First, how realistically does the widely used CCSM4 GCM simulate the observed characteristics of extreme Arctic cyclones and how sensitive are these events to the horizontal resolution of the model? Second, do other GCMs generate such storms and, if so, are there any common characteristics among models that successfully do so? Third, does the preferred location of these systems and their impacts shift as the cyclogenetic baroclinic zone induced by the sea ice margin migrates poleward with time? Fourth, what do these state-of-the-art climate models suggest about changes in the frequency vs. intensity of extreme Arctic cyclones?

## APPROACH

I am targeting these objectives through a retrospective analysis of the transient 20th century simulations (spanning years 1850-2005) among the GCMs participating in the latest Coupled Model Intercomparison Project (CMIP5). The output from various models is becoming available and eventually should include around 20 GCMs with widely varying resolutions. These simulations will be compared with a new atmospheric reanalysis data set covering almost this entire period (1871-2008) from NOAA's Earth System Research Laboratory: the 20th Century Reanalysis, version 2, available at www.esrl.noaa.gov/psd/data/gridded/data.20thC_ReanV2. This data set is described in detail by Compo et al. (2010) and provides various atmospheric fields, including sea level pressure, on daily and sub-daily time scales at $2^{o}$ horizontal resolution. All of this work is being conducted by the PI.

## WORK COMPLETED

I have partially completed the 1850-2005 analysis of CCSM4, the primary GCM in this analysis, and its comparison with the $20^{th}$ Century Reanalysis. For assessing these changes during this period of

# Report Documentation Page

*Form Approved*
*OMB No. 0704-0188*



| 1. REPORT DATE | 2. REPORT TYPE | 3. DATES COVERED |
|---|---|---|
| **30 SEP 2011** | | **00-00-2011 to 00-00-2011** |

| 4. TITLE AND SUBTITLE | 5a. CONTRACT NUMBER |
|---|---|
| **Simulation of Extreme Arctic Cyclones in IPCC AR5 Experiments** | 5b. GRANT NUMBER |
| | 5c. PROGRAM ELEMENT NUMBER |
| 6. AUTHOR(S) | 5d. PROJECT NUMBER |
| | 5e. TASK NUMBER |
| | 5f. WORK UNIT NUMBER |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Nelson Institute Center for Climatic Research,1225 W. Dayton Street,Madison,WI,53706** | 8. PERFORMING ORGANIZATION REPORT NUMBER |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) | 10. SPONSOR/MONITOR'S ACRONYM(S) |
| | 11. SPONSOR/MONITOR'S REPORT NUMBER(S) |

12. DISTRIBUTION/AVAILABILITY STATEMENT
**Approved for public release; distribution unlimited**

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
|---|---|---|---|---|---|
| a. REPORT | b. ABSTRACT | c. THIS PAGE | | | |
| **unclassified** | **unclassified** | **unclassified** | **Same as Report (SAR)** | **4** | |

modest greenhouse forcing, I have also made some comparisons with the model's response to much stronger greenhouse forcing during its 21st-century simulation.

## RESULTS

1. CCSM4 generates a significant increase in the strength and frequency of extreme Arctic cyclones in its 21st century simulation (2005-2100), with a maximum signal during autumn (Vavrus et al., 2011).
2. However, this same model does not show a strengthening of the most extreme Arctic cyclones during the 1850-2005 period, nor a significant change in their frequency.
3. The 20th Century Reanalysis does indicate a strengthening of the most extreme Arctic cyclones during similar time period (1871-2008), but most of this change occurs before 1920, when the data quality is questionable. The same conclusion generally holds for the reanalyzed frequencies of extreme cyclones, but this data set suggests noticeably higher occurrences in the high Arctic (poleward of 70°N) during the past 25 years.
4. CCSM4 produces more extreme polar cyclones than the Reanalysis, consistent with its bias toward low sea level pressure in the Arctic during almost every month (de Boer et al., 2011).
5. The CCSM4 simulations show an interesting shift in the location of extreme Arctic cyclones as a function of greenhouse warming (Figure 1). By the late 21st century, the model indicates a shift in the path of these storms, such that they emanate into the central Arctic Ocean from their preferred track over the North Atlantic-Barents Sea. However, this change is not effected by the modest greenhouse warming between 1850-2000, when the sea ice margin is further south and may act as a barrier for the production or migration of such extreme events.

## IMPACTS

These results have implications for navigation, economic activities, military operations, and coastal erosion. Existing Naval operations in the Arctic Ocean and adjacent seas can be adversely affected by the passage of extreme cyclones, and future operations will likely become even more sensitive to these weather systems if reduced ice cover promotes more Naval activities and enhanced storminess in the region. A recent paper by Overeem et al. (2011) documents accelerating rates of coastal erosion in permafrost bluffs along the Beaufort Sea, due to storm-generated waves coinciding with expanding areas of open water. Presumably, this erosion will worsen with time as sea ice recedes and storms intensify.

## RELATED PROJECTS

This topic is directly related to follow-up research I have recently proposed to ONR in collaboration with scientists at the National Center for Atmospheric Research (NCAR) to investigate the predictability of extreme sea ice and cyclone variations in the future, when the ice pack wanes and Arctic storms intensify. ["Predictability of Extreme Arctic Sea Ice Variations and Impacts", PIs: Steve Vavrus, Marika Holland, submitted to ONR on August 31]

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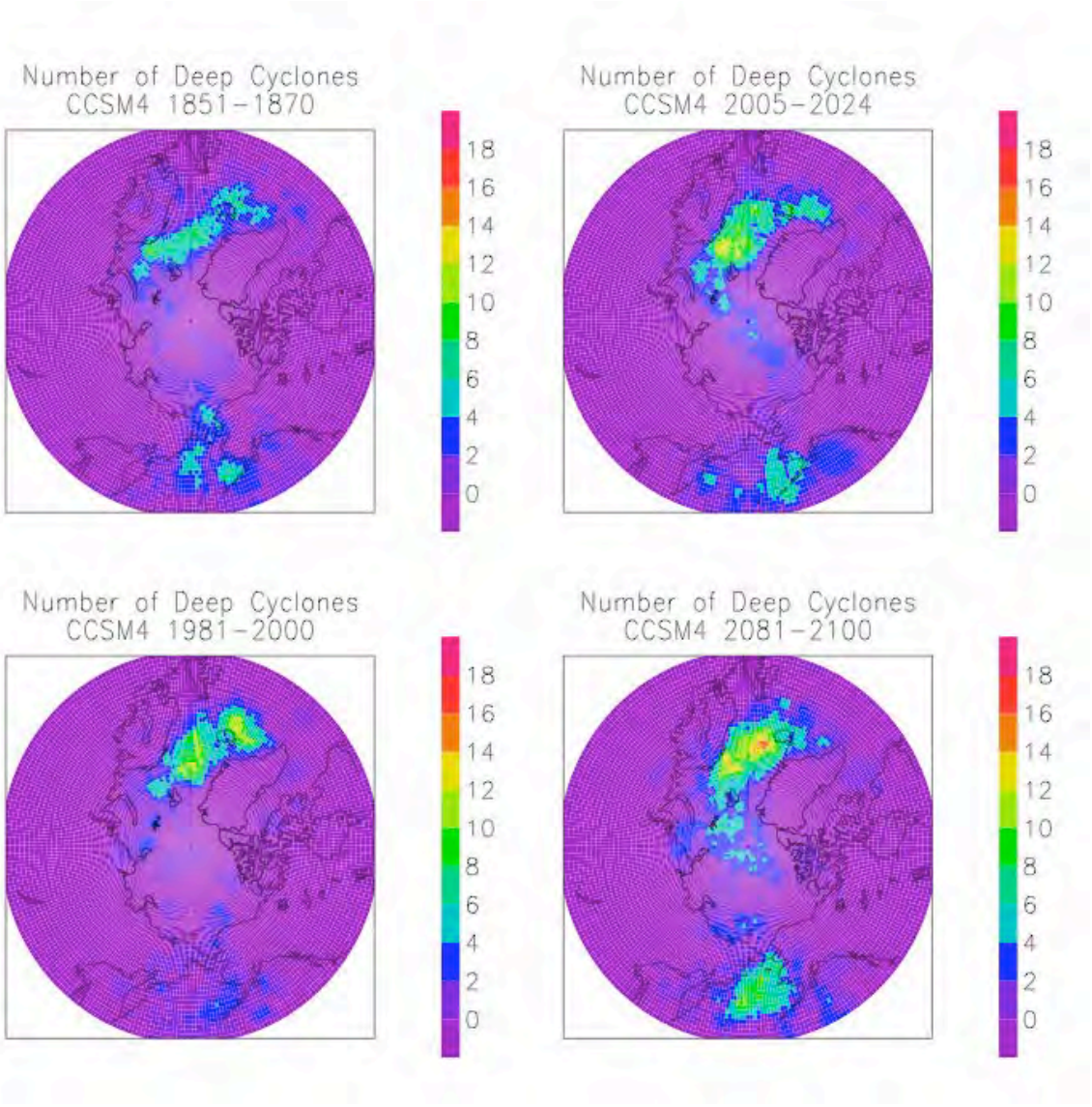


***Figure 1. Changes in the simulated frequency (events per 20-year interval) of extreme Arctic cyclones ( < 950 hPa) in the CCSM4 climate model during the middle 19th century, late 20th century, early 21st century, and late 21st century.***